US009222477B2

(12) **United States Patent**
Durham et al.

(10) **Patent No.: US 9,222,477 B2**
(45) **Date of Patent: Dec. 29, 2015**

(54) **METHOD AND SYSTEM OF SUBMERSIBLE PUMP AND MOTOR PERFORMANCE TESTING**

(71) Applicant: **GICON PUMP & EQUIPMENT, LTD.**, Abernathy, TX (US)

(72) Inventors: **R. Mark Durham**, Lubbock, TX (US); **M. Bryan Sherrod**, Wilson, TX (US); **Ronald K. Hensley**, Lubbock, TX (US); **Gary D. Grant**, Abernathy, TX (US)

(73) Assignee: **Gicon Pump & Equipment, Ltd.**, Abernathy, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/310,534**

(22) Filed: **Jun. 20, 2014**

(65) **Prior Publication Data**

US 2014/0301869 A1 Oct. 9, 2014

Related U.S. Application Data

(63) Continuation-in-part of application No. 13/083,728, filed on Apr. 11, 2011, now Pat. No. 8,776,617.

(51) **Int. Cl.**

G01L 3/00	(2006.01)
F04D 15/00	(2006.01)
F04B 51/00	(2006.01)
F04B 23/02	(2006.01)

(52) **U.S. Cl.**
CPC ***F04D 15/0088*** (2013.01); ***F04B 23/021*** (2013.01); ***F04B 51/00*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,416,586	A	11/1983	Diederich	
5,159,977	A	11/1992	Zabaras	
5,499,530	A	3/1996	Vondell	
5,589,633	A	12/1996	McCoy	
6,045,333	A	4/2000	Breit	
6,260,004	B1	7/2001	Hays	
6,450,023	B1 *	9/2002	Addie et al.	73/168

(Continued)

FOREIGN PATENT DOCUMENTS

CN	2704824 Y	6/2005
CN	201606352	10/2010

OTHER PUBLICATIONS

W.P. O'Toole, Testing New Submersible Pumps for Proper Sizing and Reduced Costs, Journal of Petroleum Technology, Feb. 1989.

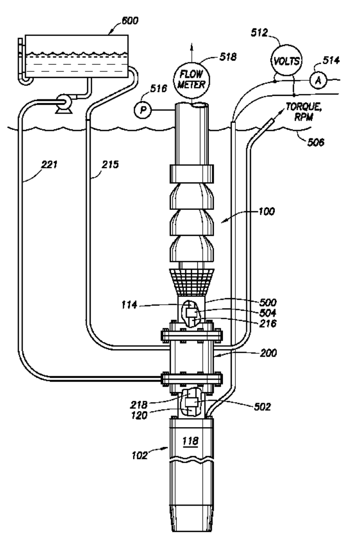
(Continued)

Primary Examiner — Lisa Caputo
Assistant Examiner — Brandi N Hopkins
(74) *Attorney, Agent, or Firm* — Mark E. Scott; Conley Rose, P.C.

(57) **ABSTRACT**

Submersible pump and motor performance testing. At least some of the illustrative embodiments are methods including: coupling a torque meter between an electric motor and a pump; and submersing the torque meter, electric motor, and pump in water. During periods of time when the torque meter, electric motor and pump are submerged in the water, the method comprises: operating the pump and the electric motor; measuring pump performance; and simultaneously measuring electric motor performance.

24 Claims, 7 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

6,468,058	B1	10/2002	Breit	
6,729,848	B1	5/2004	Hasslen	
6,776,584	B2	8/2004	Sabini	
6,911,752	B1	6/2005	Breit	
7,047,802	B2	5/2006	Seys	
7,668,694	B2 *	2/2010	Anderson et al.	702/182
7,701,106	B2	4/2010	Yuratich	
7,748,449	B2	7/2010	Bussear	
7,775,102	B2	8/2010	Haerer	

OTHER PUBLICATIONS

Joseph R. Pottebaum; Optical Characteristics of a Variable-Fequency centrifugal Pump Motor Drive, Industry Applications, IEEE Transactions on Jan. 1984, vol. 1A-20 Issue 1, p. 23-31.
Models 703 & 733 Voltage Conditioners Accurate, Versatile, User Friendly—Bulletin 374C, 2001, 2002 S. Himmelstein and Company.
MCRT 79700V Non-Contact—Dual Range Digital Torquemeters, Best Performance Under Real-World Conditions—2009, 2010 S. Himelstein and Company.

* cited by examiner

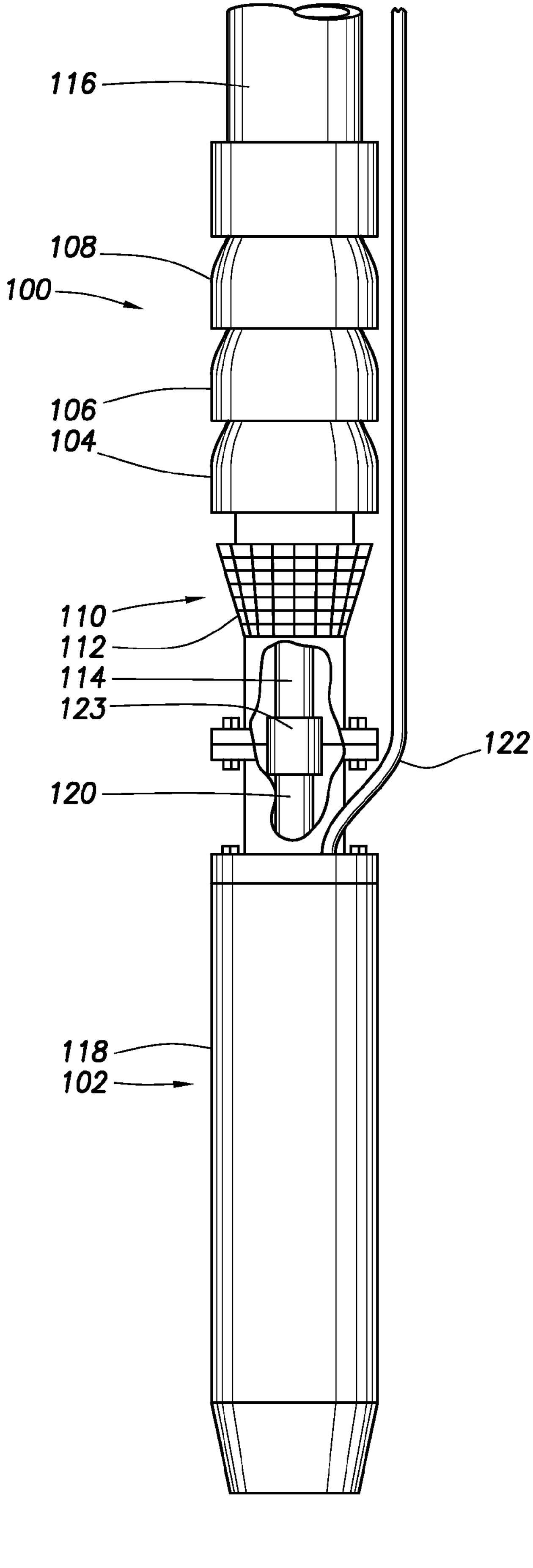


FIG. 1

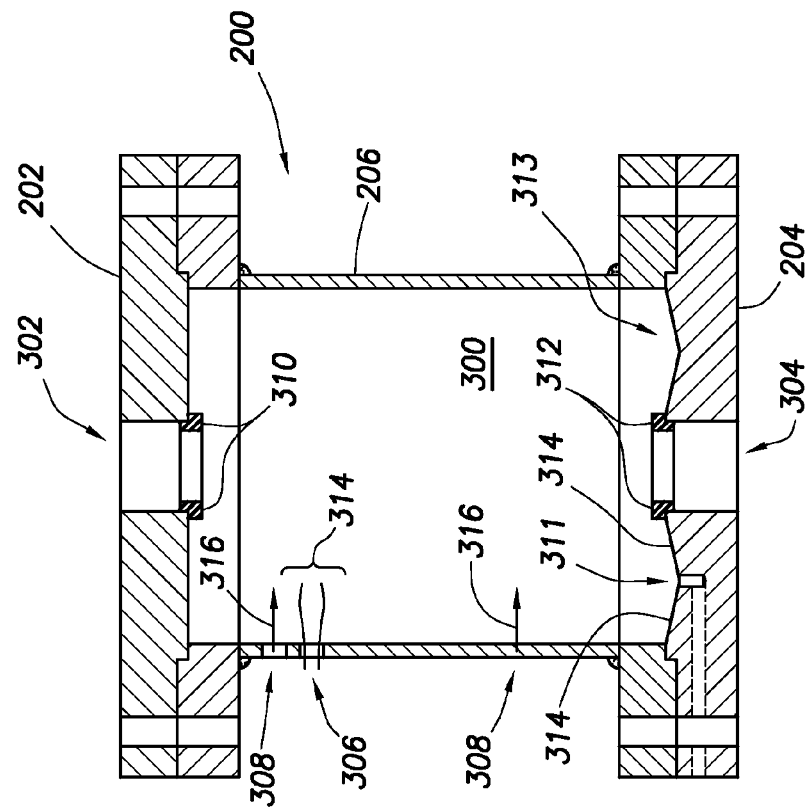

200
202
206
313
204
302
310
300
312
304
314
316
311
308
306

FIG.3

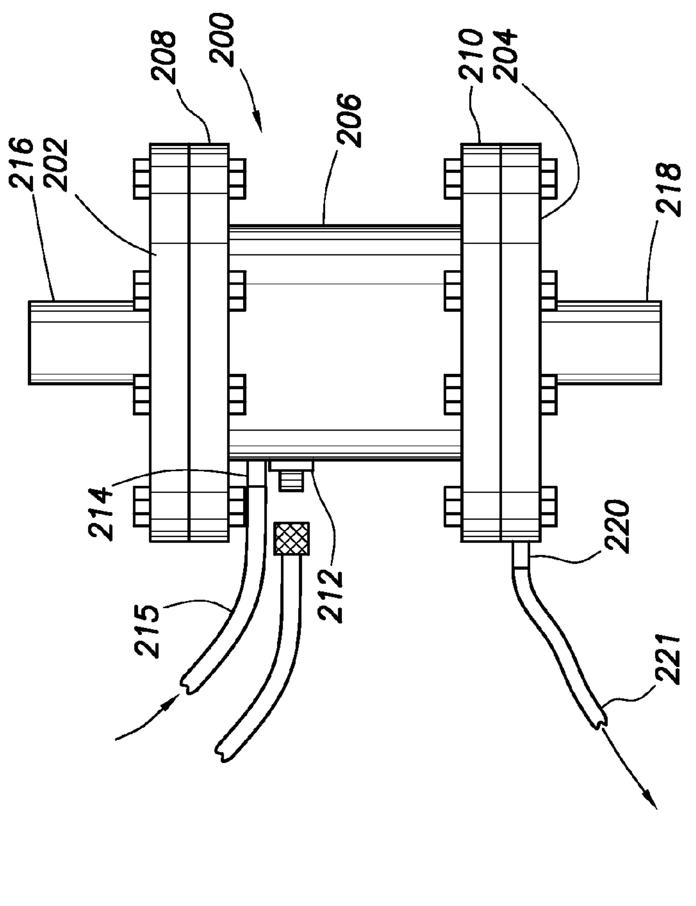

208
200
210
204
216
202
206
218
214
212
220
215
221

FIG.2

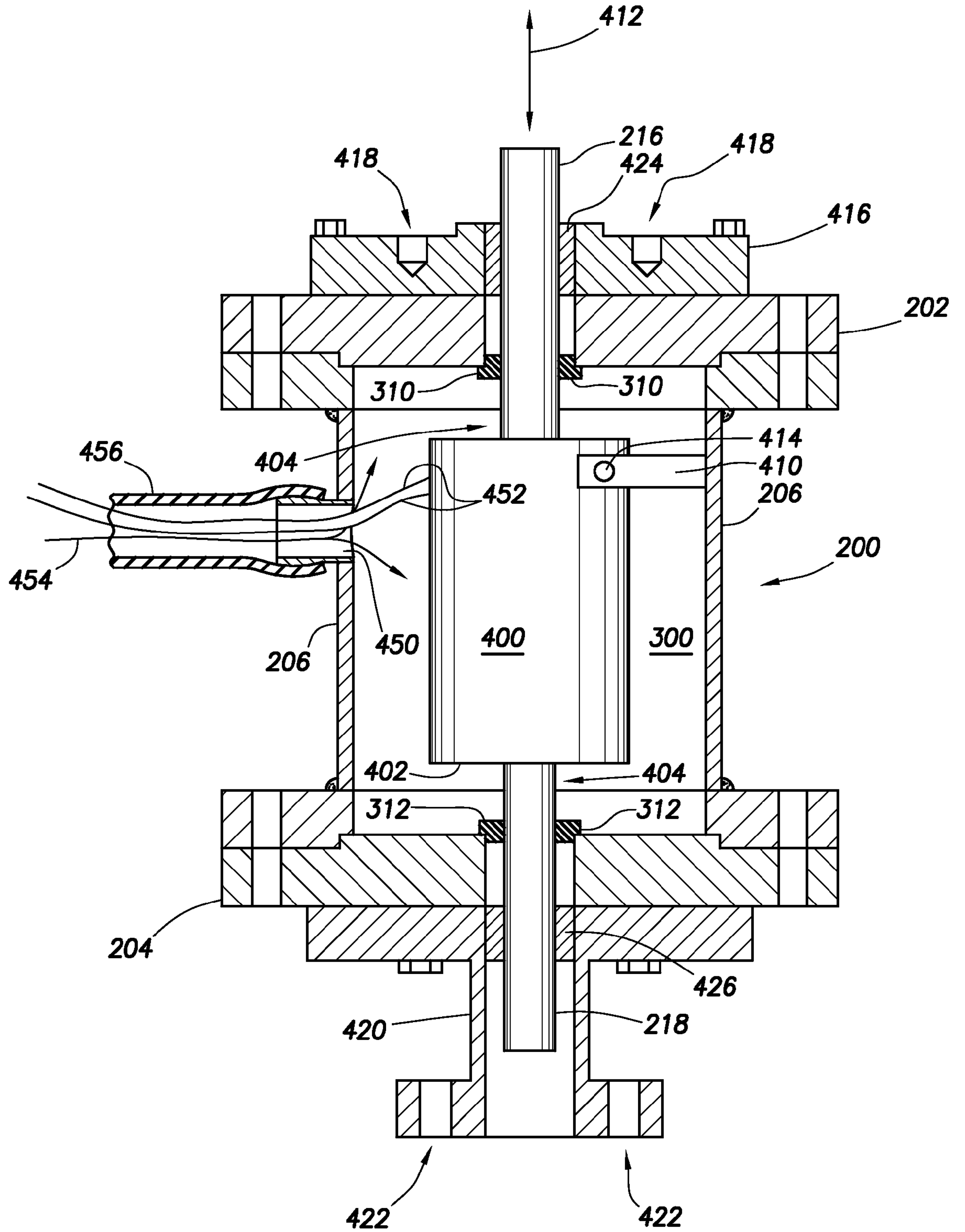
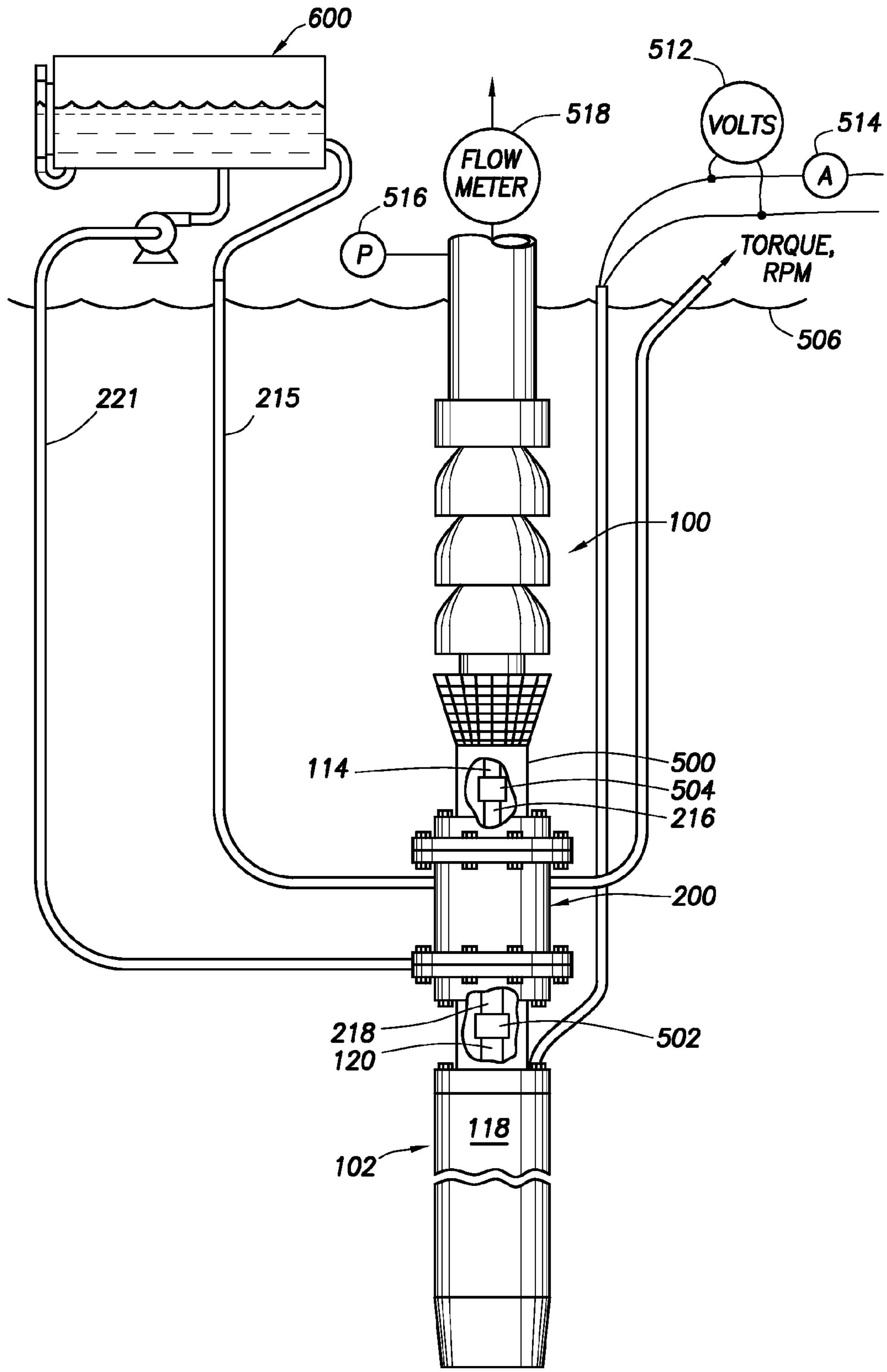

412
216
424
418
418
416
202
310
310
404
414
410
456
452
206
200
454
450
400
300
206
402
404
312
312
204
426
420
218
422
422

FIG.4



600
512
VOLTS
514
A
518
FLOW METER
516
P
TORQUE, RPM
506
221
215
100
114
500
504
216
200
218
120
502
118
102

FIG.5

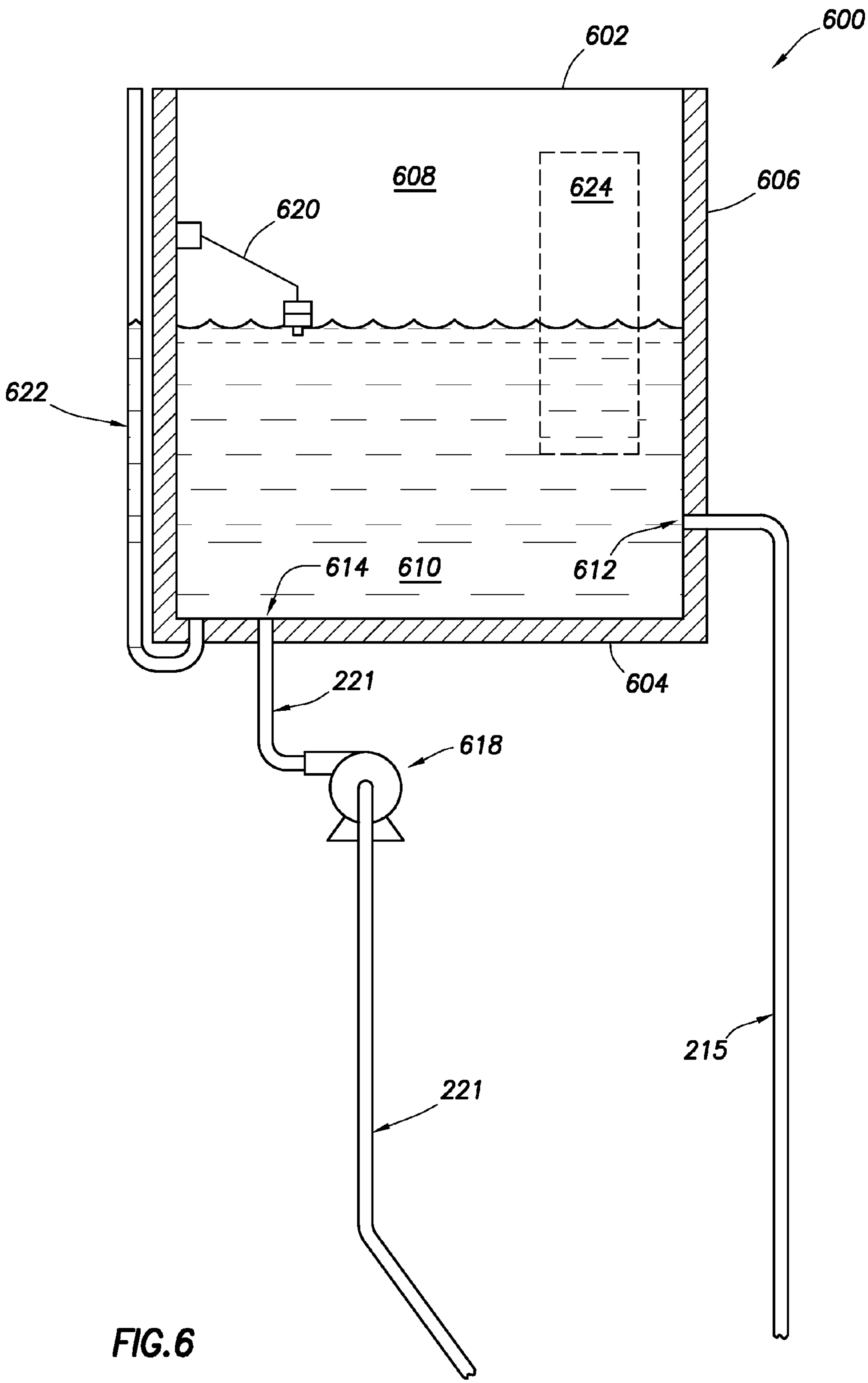


FIG.6

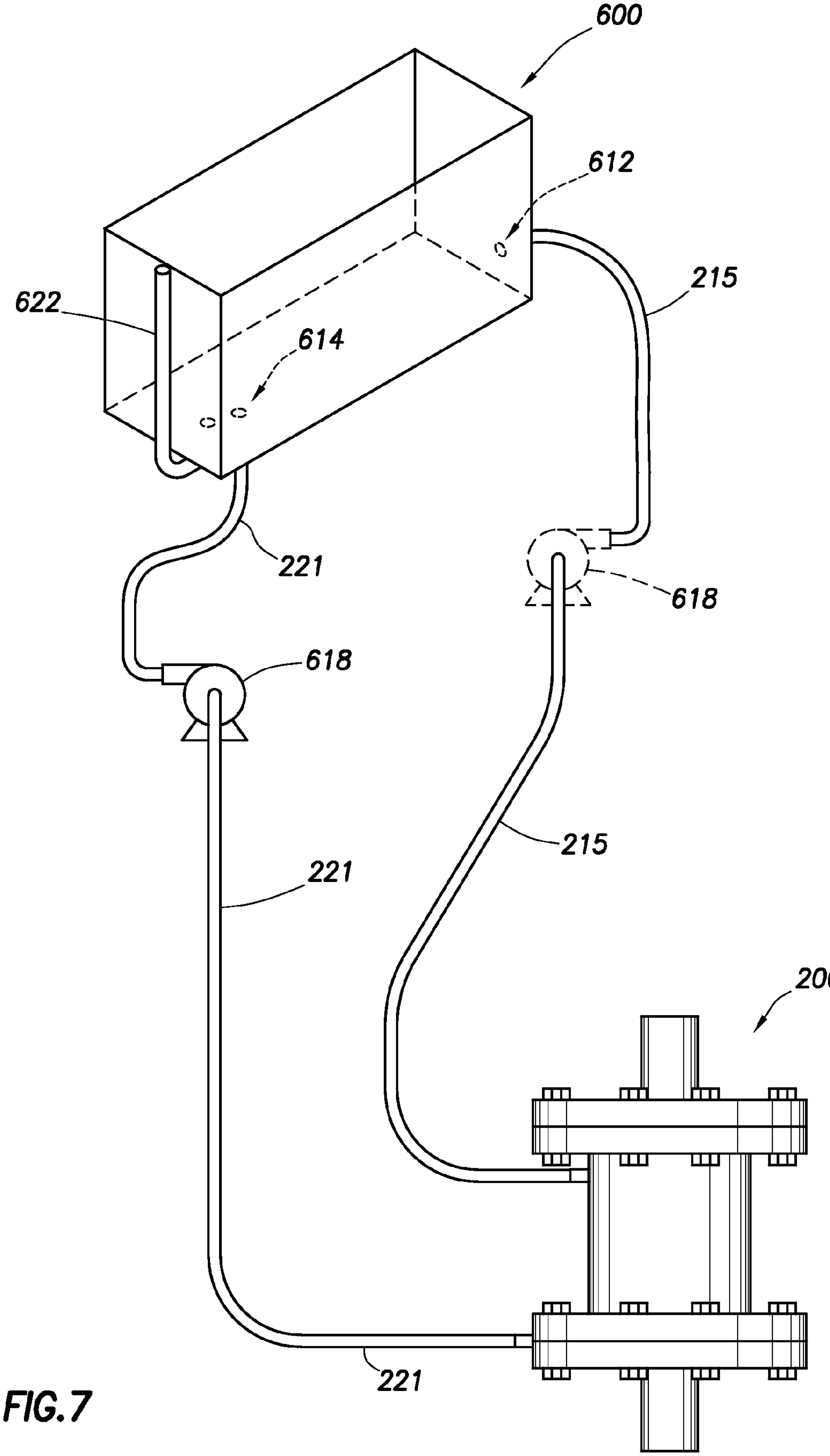


FIG. 7

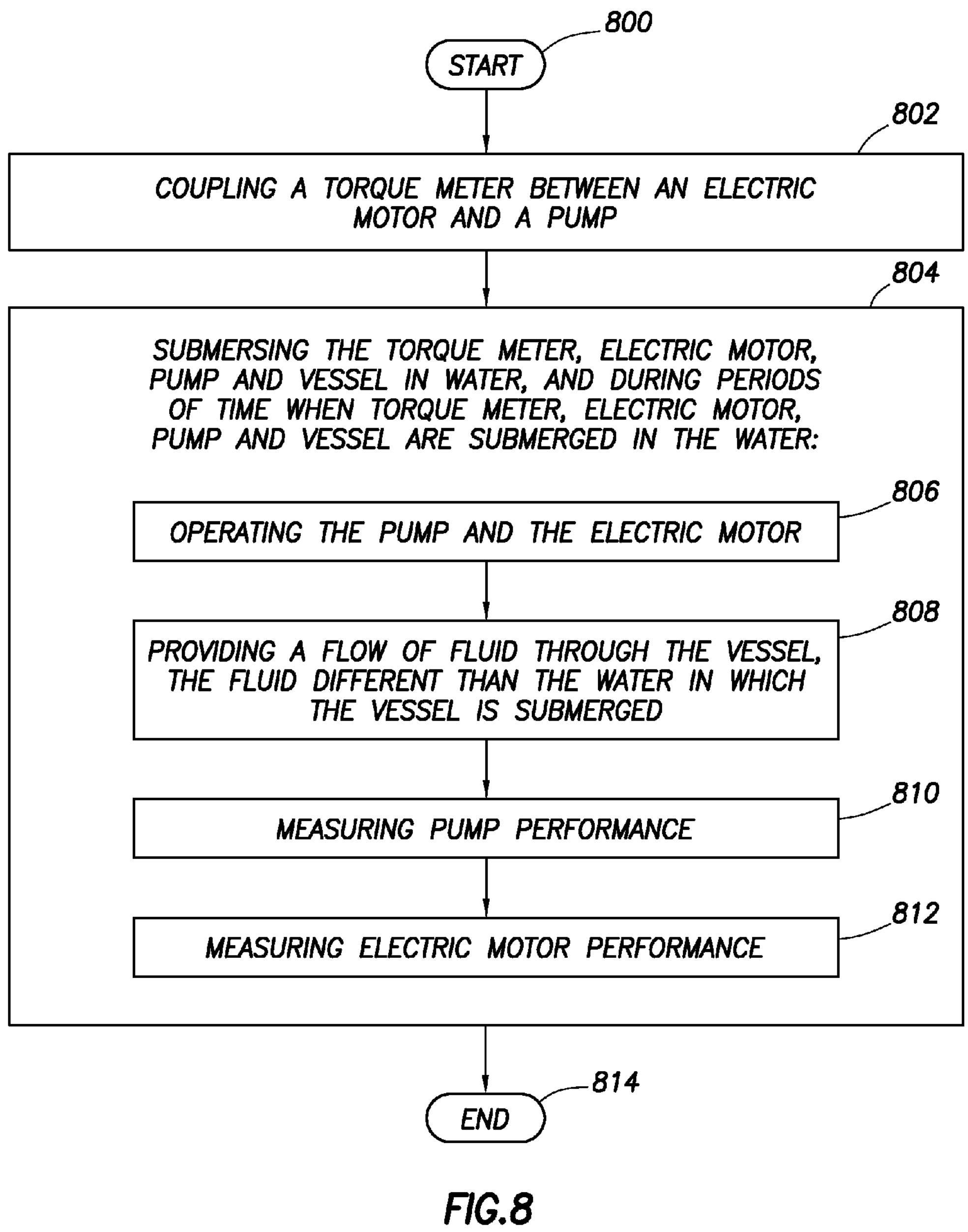

800
START
802
COUPLING A TORQUE METER BETWEEN AN ELECTRIC MOTOR AND A PUMP
804
SUBMERSING THE TORQUE METER, ELECTRIC MOTOR, PUMP AND VESSEL IN WATER, AND DURING PERIODS OF TIME WHEN TORQUE METER, ELECTRIC MOTOR, PUMP AND VESSEL ARE SUBMERGED IN THE WATER:
806
OPERATING THE PUMP AND THE ELECTRIC MOTOR
808
PROVIDING A FLOW OF FLUID THROUGH THE VESSEL, THE FLUID DIFFERENT THAN THE WATER IN WHICH THE VESSEL IS SUBMERGED
810
MEASURING PUMP PERFORMANCE
812
MEASURING ELECTRIC MOTOR PERFORMANCE
814
END

FIG.8

METHOD AND SYSTEM OF SUBMERSIBLE PUMP AND MOTOR PERFORMANCE TESTING

CROSS REFERENCE TO RELATED APPLICATIONS

This is a continuation-in-part of U.S. patent application Ser. No. 13/083,728 filed Apr. 11, 2011, which is incorporated herein by reference as if fully reproduced below.

BACKGROUND

Purchasers of industrial scale water pumping systems (e.g., cities, municipalities, water districts) compare proposed pumping systems based not only on price, but also performance. That is, even for two proposed pumping systems from two different suppliers having the same purchase price, the long term cost of the systems may be significantly different, based on parameters such as electric motor efficiency and pump efficiency.

In some cases, overall efficiency of a pump and electric motor combination may be theoretically determined by mathematically combining standard pump information for the pump (e.g., pump "curves" that relate parameters such as head pressure, flow rate, and revolutions per minute (RPM) of the pump) with standard electric motor information (e.g., information that relates motor speed, torque, electrical efficiency). However, the standard information in most cases applies to a model of pump, not a specific pump. Likewise, the standard electric motor information applies to a model of an electric motor, not a specific electric motor. Because of variations in the manufacturing process, actual pump performance and actual motor performance varies from the standard information. Thus, better information regarding performance is gathered when performance of the specific pump is measured, and likewise better information is gathered when performance of the specific electric motor is measured. Simultaneous measurement of performance of the specific pump coupled to the specific motor may provide the best overall information.

However, for vertical shaft submersible pump packages, where both the pump and the electric motor are designed for operation submersed in water and with their respective rotors held in a vertical orientation, combined performance testing in the designed operational configuration has not, to date, been achievable.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed description of exemplary embodiments, reference is made to the accompanying drawings, not necessarily to scale, in which:

FIG. **1** shows a side elevation, partial cut-away, view of a submersible pump and submersible electric motor;

FIG. **2** shows a side elevation view of a vessel comprising a torque meter in accordance with at least some embodiments; and

FIG. **3** shows a cross-sectional elevation view of a vessel in accordance with at least some embodiments;

FIG. **4** shows a cross-section elevation view of a vessel, along with an elevation view of a torque meter, in accordance with at least some embodiments;

FIG. **5** shows a side elevation, partial cut-away, view of a submersible pump and submersible electric motor coupled by way of a vessel in accordance with at least some embodiments;

FIG. **6** shows a side elevation, partial cut-away, view of a fluid storage container, in accordance with at least some embodiments;

FIG. **7** shows a perspective view of a fluid storage container, in accordance with at least some embodiments; and

FIG. **8** shows a method in accordance with at least some embodiments.

NOTATION AND NOMENCLATURE

Certain terms are used throughout the following description and claims to refer to particular system components. As one skilled in the art will appreciate, different companies may refer to a component by different names. This document does not intend to distinguish between components that differ in name but not function.

In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . ." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection or through an indirect electrical connection via other devices and connections.

"Substantially" shall mean, with respect to orientation of a rotatable shaft, the rotatable shaft is within plus or minus 45 (forty-five) degrees (angle) of a vertical orientation.

"Non-conductive oil" shall mean oil having conductivity of 2000 picosiemens per meter (pS/m) or less when measured at 25 degrees Celsius.

DETAILED DESCRIPTION

The following discussion is directed to various embodiments of the invention. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

At least some of the embodiments discussed herein are directed to measuring performance of pump packages comprising submersible pumps and submersible electric motors. At least some embodiments are directed to simultaneously measuring submersible pump performance and submersible electric motor performance while the pump and electric motor are submerged. At least some embodiments are directed to simultaneously measuring submersible pump performance and submersible electric motor performance while the pump and electric motor are submerged and while the rotatable shafts of the both the pump and electric motor are held in a vertical orientation. At least some embodiments discussed herein are directed to measuring loss of fluid from the vessel that contains the torque meter. At least some embodiments discussed herein are directed to detecting invasion of water into the vessel that contains the torque meter.

FIG. **1** shows a submersible pump and electric motor combination to orient the reader to the particular field of technology and various terms. In particular, FIG. **1** shows a side elevation, partial cut-away, view of a submersible pump **100** coupled to a submersible electric motor **102**. The pump **102** in some embodiments is a submersible centrifugal pump, sometimes referred to as a "turbine pump". As illustrated, the pump

100 has three illustrative stages **104**, **106**, and **108**, sometimes referred to as "bowls" because of their shape. In many cases, stages are individual assemblies that can be added or removed to achieve a particular design. The pump also has an inlet portion **110**, illustratively covered by a screen **112** to reduce damage to the internal components of the pump caused by debris such as rocks. The exterior portion of the stages **104-106** visible in FIG. **1** are stationary components, and thus may be referred to as a stationary pump housing.

The pump **100** further comprises a rotatable pump shaft **114**. The pump shaft **114** is the mechanism by which mechanical energy is supplied to the pump **100**, and the pump **100** thus uses the mechanical energy to pump water through the pump **100** and out the discharge piping **116**. Turbine pumps are available from many sources, such as Gicon Pumps & Equipment, LTD of Lubbock, Tex.

Still referring to FIG. **1**, the pump system illustrated in FIG. **1** further comprises a submersible electric motor **102** coupled to the pump **100**. The electric motor **102** comprises a stator or stationary motor housing **118**, within which the stator windings are housed. The electric motor **102** further comprises a rotatable motor shaft **120**, which rotatable motor shaft is rotated by the motor upon application of electrical energy to the electric motor, for example, by way of electrical cable **122**. In some embodiments, the electric motor **102** is a sealed unit that does not allow water to contact the internal electrical components. In other cases, the water is allowed to flow into the electric motor **102** (e.g., applications where the water is relatively clean and/or pure). In any event, the electric motor **102** generates heat during operation, and the water in and/or around the electric motor **102** helps dissipate the heat. For this reason, submersible electric motors cannot be operated non-submerged, or cannot be operated non-submerged for extended periods of time. Electric motors for submersible applications may operate on single phase alternating current (AC) electrical energy, multiphase AC electrical energy, direct current (DC) electrical energy, and may operate on a wide variety of voltages (e.g., 120 Volt AC, 240 Volt AC, 4160 Volt AC). Submersible electrical motors suitable for submerged operation are available from a variety of sources, such as Gicon Pump & Equipment, LTD.

The rotatable motor shaft **120** of the electric motor **102** couples to the rotatable pump shaft **114** of the pump **100** by way of a coupling **123**. Thus, rotational energy and torque created by the electric motor **102** is provided to the pump **100**, and the pump **100** in turn uses the mechanical energy to pump water by drawing the water in through the inlet portion **110**, and discharging the water through the discharge piping **116** at increased pressure.

The illustrative pump **100** and electric motor **102** of FIG. **1** are designed and constructed for operation with the rotatable shafts in a vertical orientation, as shown in FIG. **1**. While it may be possible to operate a turbine pump and/or the electric motor with the rotatable shafts in a horizontal configuration, in many cases horizontal operation of a pump and/or electric motor designed for operation in a vertical orientation may cause less than optimal performance, and further may cause damage to the internal components. Moreover, dry or only partially wetted operation of an electric motor designed for submersible operation may cause damage by improper heat transfer from the windings.

Because of the limitations associated with pumps and/or electric motors designed for submersible, vertical orientation operation, simultaneous measurement of pump and electric motor performance in design configuration has not been possible. That is, horizontal shaft pumps and horizontal shaft electric motors (i.e., non-submersible devices) may be simultaneously tested by installing a torque meter between the electric motor and the pump, along with other measurement devices (e.g., flow meters, pressure transmitters, electrical current measurement devices). The horizontal shaft devices are then operated, and the performance measured, including the torque and RPM produced by the electric motor. However, for submersible application such as shown in FIG. **1**, installing a torque meter between the pump and electric motor in submerged operation has not been possible, as the torque meter devices are electronic devices not suitable for submerged operation. There have been attempts to simultaneously test submersible pumps and submersible electric motors in a non-submersed environment, but such attempts appear to have involved only partially wetting the submersible pump and operating the devices in a horizontal configuration.

In order to at least partially address shortcomings in performance testing of submersible pumps and submersible electric motors, this specification discloses a system and method to test submersible pumps and submersible electric motors in a submersed environment. In particular, the specification discloses a vessel within which a torque meter may be disposed that enables performance testing in a submersed environment.

FIG. **2** shows a front elevation view of a vessel **200** in accordance with at least some embodiments. In particular, the vessel **200** comprises a top portion **202**, a bottom portion **204**, and a side wall **206** coupled between the top portion and the bottom portion. In at least some embodiments, the top portion **202** and bottom portion **204** are metallic flanges, and as discussed more below the top portion **202** and bottom portion **204** have apertures through which rotatable shaft portions extend. In some cases, the side wall **206** is a metallic pipe that has a circular cross section, but other cross-sectional shapes may be equivalently used. In the illustrative embodiments of FIG. **2**, the side wall **206** couples to the top portion **202** and bottom portion **204** by way of flanges **208** and **210**, respectively. In the various embodiments, the seal between the top portion **202** and the flange **208** is water tight, or substantially water tight. Moreover, the seal between the bottom portion **204** and the flange **210** is also water tight, or substantially water tight.

In accordance with the various embodiments, a torque meter is disposed within an interior volume of the vessel **200**. Torque meters are electronic devices, and thus to supply power to the torque meter, as well as to send the torque readings to a computer system that collects performance data, in some embodiments an electrical connector **212** is disposed in the sidewall in such a way that the electrical conductors protrude through an aperture (not visible in FIG. **2**) in the side wall **206**. Inasmuch as the vessel **200** is intended to be submerged during periods of time when the torque meter is in operation, the electrical connector comprises a watertight connector, such as a cannon plug available from Newark of Chicago, Ill. In other cases, the electrical connector **212**, and related aperture through the vessel **200**, may be disposed through the top portion **202** or the bottom portion **204**.

Still referring to FIG. **2**, in accordance with at least some embodiments, the interior volume of the vessel **200** is held at an elevated pressure, and thus the vessel **200** further comprises a connector **214**, and corresponding aperture, through which a pressurizing fluid, different than the water in which the vessel is submerged, flows into the interior volume of the vessel **200**. For example, during periods of time when the vessel **200** is submerged, the pressurizing fluid may be provided to the interior volume by way of a tube **215** coupled to the connector **214**, and the pressurizing fluid causing the interior volume of the vessel to be at a pressure the same or higher than the water pressure just outside the vessel **200**. For example, if the vessel **200** is submerged in water to a depth of thirty two feet, then the absolute pressure within the interior volume of the vessel **200** may be 29.4 pounds per square inch absolute (PSIA) or more. In this way, to the extent any connection between components has a small leak, or the seals (discussed more below) that seal against the rotatable shaft of the torque meter leak, the pressure of the interior volume will tend to force its way out, thus reducing the likelihood that water will enter the interior volume. The pressurizing fluid may take any suitable form such as air, nitrogen, argon, carbon dioxide, or non-conductive oil.

In accordance with a particular embodiment, in addition to pressurizing the interior volume, a monitoring system can be implemented to detect water penetration into the interior volume. In such embodiments, the vessel **200** further comprises drain aperture (not visible in FIG. **2**) fluidly coupled to the interior volume, and where the drain aperture resides at the bottom of the vessel. The drain aperture couples to a drain connector **220**, which may couple to a tube **221** that extends to the surface. During periods of time when the vessel **200** is well sealed, only the pressurizing fluid should flow through connector **220** and tube **221**. However, if water finds its way to the interior volume, gravity will tend to force the water to collect near the bottom of the interior volume or the non-conductive oil will float on the top of the water and the water will collect near the bottom of the interior volume. As will be discussed more below, the drain aperture is situated near the bottom such that any water that enters the vessel **200** will eventually be forced out the drain aperture, through the connector **220** and tube **221**, and thus be detectable at the surface.

Still referring to FIG. **2**, in accordance with a particular embodiment, in addition to pressurizing the interior volume, the pressurizing fluid is pumped out of the vessel to a fluid storage container (not shown in FIG. **2**) located above the surface of the water. In such embodiments, the pressurizing fluid flows out of the vessel by way of tube **221**. Tube **221** may be operationally connected to a pump (not shown in FIG. **2**) which pumps the pressurizing fluid from the vessel to the fluid storage container.

FIG. **3** shows a cross-sectional view of the vessel **200** with the torque meter removed. In particular, FIG. **3** illustrates the top portion **202**, bottom portion **204**, and side wall **206** as shown in FIG. **2**. Also visible in the cross-sectional view is the interior volume **300**, along with the top aperture **302**, bottom aperture **304**, connector aperture **306**, pressuring fluid aperture **308**, and drain aperture **311**. Each will be discussed in turn, starting with the top and bottom apertures **302** and **304**.

As discussed above, a torque meter is disposed within the interior volume **300**. The torque meter defines a rotatable shaft such that the torque meter can measure torque applied to the rotatable shaft and the RPM of the rotatable shaft. The rotatable shaft of the torque meter extends through the top portion **202** and bottom portion **204** through the top aperture **302** and bottom aperture **304**, respectively. In some cases a seal is disposed between the rotatable shaft of the torque meter and the stationary vessel, as illustrated by seal **310** associated with the top aperture **302**, and seal **312** associated with the bottom aperture **304**. The seals **310** and **312** may take any suitable form. For torque meters with smaller diameter rotatable shafts (and correspondingly smaller apertures **302** and **304**), o-ring seals may sufficient. For larger diameter rotatable shafts, more complex seal systems may be used, such as the ISOMAG MAGNUM-S cartridge magnetic bearing seal available from John Crane Inc. of Morton Grove, Ill. Other seals, and other seal systems, may be equivalently used.

Connector aperture **306** is shown with the electrical connector removed for clarity. However, FIG. **3** does show a plurality of conductors **314** protruding through the aperture **306**. Again, while FIG. **2** shows a cannon plug-style electrical connector, any suitable connector may be equivalently used. FIG. **3** likewise shows pressurizing fluid aperture **308** through which pressurizing fluid may flow to hold the interior volume **300** at or above the pressure of the water just outside the vessel **200**, the pressurizing fluid flow illustrated by arrow **316**.

Still referring to FIG. **3**, some embodiments the vessel comprises drain aperture **311**. Only a portion of the drain aperture **311** is visible in the cross-sectional view of FIG. **3**, but the path of the drain aperture to the connector **220** (FIG. **2**) is shown in dashed lines. As illustrated, the drain aperture is disposed at or near the bottom of the vessel such that any water that enters the vessel will find its way to the drain aperture **311**. FIG. **3** illustrates yet still further embodiments where drainage of water to the drain aperture **311** is aided by a trough **313** in the bottom portion **204**, where the trough circumscribes the bottom aperture **304**. In particular, the trough **313** defines sloped walls **314** which force water to lowest point of the trough. Though not visible in the cross-section of the FIG. **3**, the lowest point of the trough **313** may itself slope toward the drain aperture **311**, again to aid the flow of water toward the drain aperture **311**. In cases that use the flow of pressurizing fluid into the interior volume **300**, a corresponding flow of pressurizing fluid is induced in the drain aperture **311**, corresponding connector **220** (FIG. **2**), and tube **221**. In accordance with at least some embodiments, the fluid flow through the drain aperture **311** is monitored either at the surface or in the fluid storage container. If water is found, or if the rate of water accumulation measured is over a predetermined threshold, such is indicative of a leak, and thus the vessel **200** should be removed and repaired before the water damage to the torque meter occurs.

FIG. **4** shows a cross-sectional elevation view of the vessel **200** showing a torque meter installed therein, and also showing adapters to enable coupling to a pump and an electric motor. In particular, the vessel **200** has a torque meter **400** disposed within the interior volume **300**. The torque meter defines a meter housing **402**, as well as a rotatable shaft **404** that comprises a first end **216** that protrudes through the top aperture, and a second end **218** that protrudes through the bottom aperture. Torque provided to the second end **218** of the rotatable shaft **404** (e.g., from a submersible electric motor) is transferred to the first end **216** of the rotatable shaft **404** and on to other devices (e.g., a submersible pump). In the process, the torque meter **400** measures the torque transferred, and also measures the RPM of the rotatable shaft. One such torque meter that may be used is the MCRT® 79700V non-contact dual-range digital torque meter available from S. Himmelstien and Company, of Hoffman Estates, Ill. Other brands of a torque meters may be equivalently used.

In order for the torque meter **400** to measure torque and RPM, the meter housing **402** should remain rotationally stationary relative to the rotatable shaft **404**. In accordance with at least some embodiments, the system comprises a stabilizing member **410** coupled between the vessel **200** (in the illustrative case of FIG. **4**, the side wall **206**) and the meter housing **402**. In some embodiments, axial movement of the torque meter is contemplated (the axial movement illustrated by double-headed arrow **412**, and thus the stabilizing member **410** may hold the meter housing **402** rotationally stationary, but enable axial movement. As illustrated, the stabilizing member **410** is a strap (e.g., metallic, fabric, plastic) coupled by way of a fastener **414**.

Still referring to FIG. **4**, the vessel **200** with the torque meter **400** disposed at least partially therein is coupled between a submersible electric motor and a submersible pump. FIG. **4** illustrates a pump coupler **416** coupled to the top portion **202**. The pump coupler **416** enables the pump to bolt to the vessel **200**, and further enables the rotatable shaft of the pump (not shown in FIG. **4**) to align with and couple to the first end **216** of the rotatable shaft **404**. For example, an extension portion of the pump may bolt to the illustrative internally threaded bolt apertures **418**.

Likewise, the vessel **200** with the torque meter **400** disposed therein couples to a submersible electric motor. FIG. **4** illustrates a motor coupler **420** coupled to the bottom portion **204**. The motor coupler **420** enables the electric motor to bolt to the vessel **200**, and further enables the rotatable shaft of the electric motor (not shown in FIG. **4**) to align with and couple to the second end **218** of the rotatable shaft **404**. For example, the motor coupler **420** may bolt to the illustrative electric motor by way of apertures **422**. Before proceeding, it is noted that the pump coupler **416** and motor coupler **420** are merely illustrative, and may equivalently take any suitable form to match coupling mechanisms of the pump and electric motor respectively.

Still referring to FIG. **4**, in a particular embodiment the system further comprises an upper bearing **424** and a lower bearing **426**. As illustrated, the upper bearing **424** is disposed between the pump coupler **416** and the rotatable shaft **404**, and the lower bearing **426** is disposed between the motor coupler **420** and the rotatable shaft. In embodiments where bearings **424** and **426** are used, the bearings may be of any suitable type, such as bronze bearings. It is noted that bearings **424** and **426** may be omitted, particularly for smaller rotatable shaft **404** diameters and/or lower torque systems. Moreover, in some cases the seals **310** and **312** may also serve as bearings.

FIG. **4** also illustrates alternative embodiments where the pressurizing fluid for the interior volume **300** and the electrical conductors that couple to the torque meter **400** are provided through the same aperture. In particular, FIG. **4** illustrates aperture **450** through the side wall **206**. Aperture **450** is sized such that not only can electrical conductors **452** protrude through the aperture **450**, but also the pressurizing fluid flow (illustrated by arrows **454**) also flows through the aperture. In such embodiments, the electrical conductors from the surface extend through the tube **456**, and are thus are kept in a dry environment, not exposed to the water surrounding the vessel **200**.

FIG. **5** shows a system in accordance with at least some embodiments. In particular, FIG. **5** shows an electric motor **102** coupled to water pump **100** by way of vessel **200**. More particularly still, the stationary motor housing **118** couples to the vessel **200**, and the vessel **200** couples to the stationary pump housing **500**, and as illustrated the water pump **100**, vessel **200** and electric motor **102** are suspended by the outlet pipe. Moreover, the rotatable shaft **120** of the electric motor **102** couples to the second end **218** of the rotatable shaft **404** of the torque meter by way of a coupling **502**, and the rotatable shaft **114** of the water pump **100** couples to the first end **216** of the rotatable shaft **404** of the torque meter by way of a coupling **504**. Thus, the stationary components are coupled together, and the rotatable shafts are coupled together, and the entire assembly is submerged below the surface **506** of the water.

In operation, the pressurizing fluid may be provided to the vessel by way of tube **215** and return by way of tube **221**. The pressurizing fluid that returns may be checked for water entrainment. Water entrainment may be indicative of a water leak into the interior volume of the vessel **200**, and thus may dictate removal of the assembly from the submersed orientation to ensure the torque meter is not damaged.

While the electric motor **102** is operating, the voltage supplied to the electric motor **102** may be measured (such as by voltage meter **512**), and simultaneously the amperage drawn may be measured (such as by amp meter **514**). From voltage and amperage, the electrical power provided to the electric motor may be determined. Moreover, while the electric motor is operating the head pressure developed by the pump **100** may be measured (such as by pressure gauge **516**), and the flow of water may be measured (such as by flow meter **518**). Further, while the electric motor **102** is operating and the pump **100** is producing pressure and flow, the torque provided by the electric motor **102** may be measured by way of the torque meter in the vessel **200**. Likewise, the RPM of the electric motor (and thus the pump) may also be measured by the torque meter. Using such information, and possibly by restricting the flow of water from the pump (such as by a surface valve), the performance of the both the pump and motor may be simultaneously measured over a range of pump flow rates.

The various embodiments have presented the vessel **200** and internal torque meter as a short term test mechanism for performance testing; however, in other embodiments the vessel **200** and internal torque meter may be a permanent or semi-permanent installation that enables measuring performance of the pump and electric motor over time, for example, to gauge or rate performance degradation.

FIG. **6** shows a cross-sectional view of a fluid storage container in accordance with at least some embodiments. The fluid storage container **600** is a container that stores and contains the fluid used to pressurize the vessel. The fluid storage container can be made of any suitable material, such as metal or plastic, and one such fluid storage container is a 55 gallon drum available from W.W. Grainger, Inc.

In particular, FIG. **6** shows a fluid storage container **600** that comprises a top portion **602**, a bottom portion **604**, and a side wall **606** coupled between the top portion and the bottom portion. Also visible in the cross-sectional view is the interior volume **608** and pressurizing fluid **610**. In one example system, pressurizing fluid **610** flows by force of gravity through aperture **612** and tube **215** to the vessel. The pressurizing fluid returns to the fluid storage container by way of tube **221** and through aperture **614**. In some embodiments the pressurizing fluid may be returned to the fluid storage container by using pump **618** to pump the pressurizing fluid from the vessel to the fluid storage container by way of tube **221**.

Still referring to FIG. **6**, in some embodiments it may be desirable to determine if a leak exists such that pressurizing fluid is being lost. By measuring the fluid level, one can determine whether pressurizing fluid may be leaking from the vessel **200**; from the fluid storage container **600**; from tube **221**; from tube **215**, or from any other component. Therefore, in such embodiments, a fluid level indicator may be present, such as a floating fluid level sensor **620** or a sight glass fluid level monitor **622**. One such floating fluid level sensor **620** that may be used is a single point float switch available from Gems™ Sensors & Controls, of Plainville, Conn. Other suitable fluid level indicators **624** may also be used, including: demarcations of level on the wall of the fluid storage container, a hydrostatic fluid level measurement device, a load cell, a strain gauge device, a magnetic level gauge, a capacitance transmitter, a magnetostrictive level transmitter, or an ultrasonic, laser, or radar level transmitter.

Further, still referring to FIG. **6**, in accordance with some embodiments, it may be desirable to determine whether water is entering the fluid storage container **600** or the vessel **200** and contaminating the pressurizing fluid **610**. FIG. **6** shows a sight glass **622** which may operate to detect water contamination. Further, water contamination may also be indicative of a leak into the interior volume of the vessel **200**. In certain embodiments where the pressurizing fluid **610** is non-conductive oil, one may measure contamination of the pressurizing fluid by visually inspecting the pressurizing fluid **610** for the presence of water on bottom portion **604** of the fluid storage container **600** using sight glass **622**. Contamination of the pressurizing fluid **610**, by not only water but by any substance other than the pressurizing fluid **610**, may be measured using any of the fluid level indicators previously identified.

FIG. **7** shows a perspective view of a fluid storage container **600** in accordance with at least some embodiments. FIG. **7** shows a fluid storage container **600** with sight glass **622**. FIG. **7** demonstrates that, in accordance with some embodiments, the pressurizing fluid **610** can be pumped by pump **618** out of the fluid storage container **600** by way of aperture **612** and through tube **215** to vessel **200**. FIG. **7** also shows that the pressurizing fluid **610** may also be pumped from the vessel **200** to the fluid storage container **600** by pump **618** though tube **221**, and enter the fluid storage container **600** by way of aperture **614**.

FIG. **8** shows a method in accordance with at least some embodiments. In particular, the method starts (block **800**) and comprises: coupling a torque meter between an electric motor and a pump (block **802**); submersing the torque meter, electric motor, pump and vessel in water (block **804**). During periods of time when the torque meter, electric motor, pump and vessel are submerged in the water: operating the pump and the electric motor (block **806**); providing a flow of fluid through the vessel, the fluid is different than the water in which the vessel is submerged (block **808**); measuring pump performance (block **810**); and simultaneously measuring electric motor performance (block **812**). Thereafter, the method ends (block **814**).

The above discussion is meant to be illustrative of the principles and various embodiments of the present invention. Numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. For example, the rotatable shaft of the torque meter is shown to have the same length extending from each side of the housing; however, the rotatable shaft need not be of equal length on each side. Moreover, the vessel is presented as metallic to enable the system to be used in high torque situations; however, in lower torque cases, the vessel may be constructed of other materials, such as plastics. In cases where the manufacturer of the vessel within which the torque meter is installed is confident the seals will not leak, the use of pressurizing fluid may be equivalently omitted. It is intended that the following claims be interpreted to embrace all such variations and modifications.

What is claimed is:

1. A method comprising:

coupling a torque meter between an electric motor and a pump;

submersing the torque meter, electric motor, and pump in water, and during periods of time when the torque meter, electric motor and pump are submerged in the water:

operating the pump and the electric motor;

providing a flow of fluid through the vessel, the fluid different than the water in which the vessel is submerged;

measuring pump performance; and simultaneously measuring electric motor performance.

2. The method of claim **1** wherein providing the flow of fluid further comprises feeding the fluid under force of gravity to the vessel from a fluid storage container residing above a surface of the water.

3. The method of claim **2** wherein providing further comprises pumping the fluid from the vessel back to the fluid storage container.

4. The method of claim **1** further comprising detecting loss of the fluid from the vessel into the water.

5. The method of claim **4** wherein detecting loss of the fluid further comprises measuring level of the fluid in a fluid storage container fluidly coupled to the vessel.

6. The method of claim **1** further comprising detecting invasion of water into the vessel.

7. The method of claim **6** wherein detecting invasion of water further comprises:

recirculating the fluid from the vessel to a fluid storage container disposed above a surface of the water; and then

detecting water in the fluid storage container.

8. The method of claim **1** wherein providing the flow of fluid further comprises providing the flow of fluid being a non-conductive oil.

9. The method of claim **1** wherein measuring pump performance further comprises, simultaneously:

measuring torque provided to the pump by the electric motor;

measuring rotational rate at input shaft of the pump;

measuring water pressure produced by the pump;

measuring water flow produced by the pump.

10. The method of claim **1** wherein measuring motor performance further comprises, simultaneously:

measuring rotational rate of an output shaft of the electric motor;

measuring torque provided by the electric motor; and

measuring electrical power provided to the electric motor.

11. The method of claim **1** further comprising monitoring fluid flow carried within a tube fluidly coupled to the interior volume of the vessel, the tube distinct from the tube that provides fluid to the vessel, and the monitoring during periods of time when the torque meter is submersed in the water.

12. The method of claim **1** wherein the pump defines a rotatable shaft, the torque meter defines a rotatable shaft, and the electric motor defines a rotatable shaft, and wherein operating the pump and the electric motor further comprises operating with the shafts in a substantially vertical orientation.

13. The method of claim **1** wherein submersing further comprises suspending the pump, torque meter, and electric motor in the water.

14. The method of claim **1** wherein measuring pump performance further comprises measuring at least one selected from the group consisting of: head; fluid flow; and power provided to the pump.

15. The method of claim **1** wherein measuring electric motor performance further comprises measuring at least one selected from the group consisting of: voltage provided to the electric motor; current drawn by the electric motor; revolutions per unit time of a rotor of the electric motor; torque provided by the rotor of the electric motor.

16. A system comprising:

a water pump that defines a rotatable pump shaft and a stationary pump housing, the water pump submersed in water, and the pump shaft in a substantially vertical orientation;

an electric motor that defines a rotatable motor shaft and a stationary motor housing, the rotatable motor shaft coupled to the rotatable pump shaft, the electric motor submerged in the water below the water pump, and the rotatable motor shaft in a substantially vertical orientation;

a torque meter at least partially disposed within a sealed vessel, the vessel submersed in the water, and the torque meter comprising:

a rotatable torque meter shaft;

a first end of the torque meter shaft protrudes from the vessel and is coupled to the pump shaft; and

a second end of the torque meter shaft protrudes from the vessel and is coupled to the motor shaft such that torque provided by the electric motor is coupled to the pump shaft through the torque meter;

wherein the vessel is coupled between the stationary pump housing and the stationary motor housing;

a fluid storage container disposed above a surface of the water, the fluid storage container defines an interior volume containing a fluid, and the interior volume fluidly coupled to an interior volume of the sealed vessel;

a fluid level indicator in operational relationship to the fluid storage container, the fluid level indicator configured to indicate level of the fluid within the interior volume of the fluid storage container; and

a fluid contamination indicator in operational relationship to the fluid storage container, the fluid contamination indicator configured to indicate invasion of water into the sealed vessel.

17. The system of claim **16** a fluid pump fluidly coupled between the fluid storage container and the interior volume of the sealed vessel, wherein the pump is configured to pump fluid from the interior volume of the sealed vessel to the fluid storage container.

18. The system of claim **16** further comprising a pump fluidly coupled between the fluid storage container and the interior volume of the sealed vessel, wherein the pump is configured to pump fluid from the fluid storage container to the sealed vessel.

19. The system of claim **16** wherein the fluid level indicator is at least one selected from the group consisting of: a sight glass in operational relationship with the interior volume of the fluid storage container; demarcations of level associated with walls of the fluid storage container; an electronic level indicator in operational relationship to the fluid; a float assembly floating at a surface of the fluid; a hydrostatic fluid level measurement device, a load cell, a strain gauge device, a magnetic level gauge, a capacitance transmitter, a magnetostrictive level transmitter, and an ultrasonic, laser, or radar level transmitter.

20. The system of claim **16** wherein the fluid contamination indicator is at least one selected from the group consisting of: a sight glass in operational relationship with the interior volume of the fluid storage container; demarcations of level associated with walls of the fluid storage container; an electronic level indicator in operational relationship to the fluid; a float assembly floating at a surface of the fluid;

a hydrostatic fluid level measurement device, a load cell, a strain gauge device, a magnetic level gauge, a capacitance transmitter, a magnetostrictive level transmitter, and an ultrasonic, laser, or radar level transmitter.

21. The system of claim **16** wherein the fluid is non-conductive oil.

22. The system of claim **16** wherein the fluid level indicator and the fluid contamination indicator are a single sight glass.

23. The system of claim **16** further comprising a pressurizing fluid that flows from the fluid storage container through a first aperture into the interior volume, wherein the pressurizing fluid causes the pressure within the interior volume to be greater than pressure of the water outside the vessel.

24. The system of claim **16** further comprising a second aperture through the vessel through which a pressurizing fluid flows from a fluid storage container into the interior volume, wherein the pressurizing fluid causes the pressure within the interior volume to be greater than pressure of the water outside the vessel.

* * * * *